Moisture Flow

Moisture flow through buildings is essential knowledge for the energy specialist. This section explains the way water and water vapor move through a building and its materials.

To learn about moisture and health, see "Moisture Management" on page 245.

Characteristics of H_2O

A molecule of water contains two relatively small hydrogen atoms and one relatively large oxygen atom composing the compound with the chemical name H_2O. Water is the only common substance that we encounter in all three of the states of matter: solid, liquid, and gas.

Unlike many other substances, the solid state (ice) is less dense than the liquid. Liquid water expands when it freezes. If the liquid freezes while it is in or near a building material, the movement of the expanding ice can damage the building material.

A water molecule is like a magnet because it has two oppositely charged poles. Liquid water molecules clump together with their positive and negative poles facing one another.

Individual water vapor molecules, floating around in the air, are about one-third of the size of the other air molecules: nitrogen and oxygen. A very small water droplet (fog) is about 3500 times the diameter of a water molecule. A material, like Tyvek and Gortex, can block both liquid water and air, while letting water vapor through. These special materials have pores big enough to pass water vapor but small enough to block air molecules and the smallest water droplets. A material, like polyethylene or aluminum foil, that blocks water vapor also blocks air and liquid water because of this size consideration.

Moisture and Materials

We classify materials as either porous or non-porous to water and water vapor. Porous materials include wood products, insulation, and masonry materials. Non-porous materials, which are impervious to moisture, include glass, plastic, steel, and aluminum.

Adsorption is when porous materials attract and store individual water molecules on the surfaces of their pores. The water-vapor molecules cling to walls of the pores. In drier conditions, the pores *desorb* the water vapor, clinging to their surfaces, and the water vapor exits the material. Many materials such as wood or brick expand and contract with the adsorption and desorption of water vapor.

If the porous material continues adsorbing water vapor, the pores eventually run out of surface area to hold the vapor molecules on the surface of the pores. Then the water molecules start to clump into a liquid, filling the pores with liquid water.

Moisture Movement through Buildings

Moisture enters buildings and moves through them as both liquid water and water vapor. This movement happens in four ways.

- *Liquid flow.* Driven by gravity, or pressure differences, water flows into a building's holes and cracks. Roof leaks and plumbing leaks can deposit large amounts of water in a home.
- *Capillary seepage.* Liquid water creates a suction of its own as it moves through tiny spaces within and between building materials. This capillary suction draws water seepage from the ground. Seepage also redistributes water from leaks, spills, and condensation.
- *Air movement.* Air movement carries water vapor into and out of the building and its cavities. Air pressure difference is the driving force for this air movement, and holes in the building shell are the leakage paths. If the air

reaches saturation (also called the dew point), condensation will occur.

- *Vapor diffusion.* Water vapor will move through solid objects depending on their permeance and the vapor pressure.

Water Vapor and Humidity

Water vapor is lighter than air and the water vapor molecule is smaller than air's other molecules — nitrogen and oxygen. Therefore, water vapor can rise faster and squeeze through smaller microscopic spaces than air. When water vapor moves through a solid material, this is called vapor diffusion.

Materials vary in their permeability to water vapor. Porous materials like brick and insulation transmit water vapor relatively rapidly and are said to have a high permeability. Plywood and drywall have a medium permeability. House wrap is a specially designed material that repels water while letting water vapor through because of house wrap's high permeability. Metals and plastic films, often called *vapor barriers*, slow vapor diffusion to a trickle.

A force called vapor pressure drives vapor diffusion. *Vapor pressure* is created by a difference in the amount of water vapor in two bodies of air, which are separated by some barrier, like a wall. The amount of water vapor in the air — called *absolute humidity* or *humidity ratio* — is expressed in pounds of water vapor per pound of dry air. Vapor pressure is the difference in absolute humidity between two air masses. The greater the vapor pressure, the faster water vapor flows through building materials separating the two air masses.

Relative humidity (rh) — the percentage of the maximum moisture that air at a given temperature can hold — is 100% when the air is saturated with moisture. Add more moisture to saturated air, and moisture condenses on cool objects. Relative humidity is 50% when the air at a particular temperature is only half saturated with water vapor. The moisture content of building materials is directly related to the relative humidity of the air surrounding them.

Converting Energy for Home Use

In all homes, energy is converted from one form to another — electricity to light, gas to heated water — within its walls to provide occupants comfort, water heating, refrigeration, lighting, entertainment, and a variety of other services.

Combustion Heating

Most homes in the United States are heated by combustion heating systems. When the carbon and hydrogen atoms in fuel molecules mix with oxygen and a flame, the chemical chain reaction we call burning begins. Heat is liberated in the chemical process, and we use this heat for space and water heating.

The heat from the flame and hot gases heats a metal structure, called a heat exchanger, which then heats air or water. The flame heats the heat exchanger first and foremost by radiation and also by convection of its combustion gases. Pipes or ducts carry the heated air or water to the building's rooms. The transfer of chemical energy into heat at the flame is usually more than 99% efficient. However the farther the heat travels away from the flame, into the heat exchanger and through the distribution system, the more heat is lost. These progressive heat losses make most central heating systems less than 70% efficient at converting the fuel's chemical energy to useful heat for the home.

See "Combustion Heating Basics" on page 142.